Seabed Geo-Acoustic Parameters and Scattering Model from Low Frequency Measurements in Shallow Water

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LONG-TERM GOALS

The long-term goals of this work are: to develop a practical seabed geo-acoustic model and a practical scattering model for predicting sound transmission, reverberation and their spatial coherence in shallow water (SW).

OBJECTIVES

The scientific objectives of this research include: (1) To characterize sea bottom geo-acoustic parameters (sound speed and attenuation) and bottom scattering function from both sound propagation and reverberation, measured in a low frequency (LF) range of 50-2000Hz. (2) To reveal the physics of the LF field-inverted sediment acoustic parameters and bottom scattering function (as a function of angle and frequency).

APPROACH

The Seabed is the king of the shallow-water acoustic problem. In SW with fast seabottoms $(C_b / C_w > 1)$, the long-range sound propagation/reverberation is dominated by lower order modes that are interacted with top layer of seabed at small grazing angles. Thus, an effective seabed geo-acoustic model, derived from different long-range field characteristics, is more important and more practical for sonar performance prediction than detailed layering structure information obtained from short-range inversions.

A bottom scattering function as a function of frequency and angle is the kernel problem for SW reverberation. The LF bottom scattering function at low grazing angles can not be directly measured in shallow water, but inverted from long-range reverberation. However, the long-range reverberation depends on both bottom geoacoustic parameters and scattering function by inter-parameter correlation. Without reliable data of seabed geoacoustic parameters, the reverberation-derived bottom scattering function is often questionable.

Therefore, the scientific objectives of this year's research focus on: (1) To analyze and review the LF measurements, made at 20 locations in different coastal zones around the world, to derived a LF seabed sound speed and attenuation as a function of frequency. (2) To compare the LF field-derived seabed acoustic parameters with popular sediment acoustic models. (3) To compared the LF field-

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14. ABSTRACT
The long-term goals of this work are: to develop a practical seabed geo-acoustic model and a practical scattering model for predicting sound transmission, reverberation and their spatial coherence in shallow water (SW).

15. SUBJECT TERMS

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derived attenuation data with directly measured mid- to high-frequency data to see if they can smoothly be linked each other. (4) To measure 3-D acoustic spatial coherence for the SW06 site as a function of frequency, distance and hydrophone separation for geo-acoustic inversion.

RESULTS

(1) The seabed attenuations, inverted from different acoustic field characteristics at 20 locations in different coastal zones around the world, exhibit similar magnitude and nonlinear frequency dependence below 2000 *Hz*. The results are shown in Figure 1. The resulting effective sound attenuation in sandy/silty bottoms can be expressed by

$$\alpha\,(dB/m) = (0.37 \pm 0.01)(f/1000)^{(1.80\pm 0.02)} \qquad \text{for 50-1000 Hz.}$$

(2) The corresponding average sound speed ratio at the bottom-water interface in the 50-600 Hz range is 1.061 ± 0.009.

(3) The LF sound speeds and attenuations of the sandy bottoms are smoothly joined with the SAX99/04 measurements for mid- and high-frequencies and also match Hamilton's prediction on sound attenuation very well around 1 *kHz*. A combination of the LF data with the SAX99/04 data as well as other mid- to high-frequency measurements offers a reference broadband data set of sound speed and attenuation for sandy bottoms in shallow water in a frequency range of 50-400,000 *Hz*.

(4) Both LF field-derived sound speed and attenuation in the bottom can be equally well described by the Biot-Stoll model, the Buckingham model, the Chotiros-Isakson BICSQS model and Pierce-Carey/Williams LF model. The effective geophysical parameters for these acoustic models have been derived. Comparisons of the LF field-derived sound attenuation data with these four models are plotted in Figure 2.

(5) 3-D acoustic spatial coherence for the SW06 site has been analyzed using two L-shape array data. Preliminary results show that the coherence data can be used to invert bottom sound speed and attenuation as well as effective bathymetry variance. As an example, Figure 3 shows the inversion for bottom sound speed and attenuation from longitudinal coherence.

(6) LF Reverberation data from several sites have been analyzed for future derivation of bottom scattering function.

IMPACT/APPLICATIONS

A combination of the LF field-inverted data with the SAX99, SAX04 and other high frequency measurements offer a reference broadband data set in the 50-400,000 *Hz* range for sonar prediction and sediment acoustics modeling.

PUBLICATIONS

1. J.X. Zhou, X. Z. Zhang and D. K. Knobles, "Low-frequency geoacoustic model for the effective properties of sandy seabottoms," J. Acoust. Soc. Am. 125 (5), 2847-2866 (2009).

2. L. Wan, J.X. Zhou, P.H. Rogers and D.K. Knobles, “Spatial coherence measurement from two L-shape arrays in shallow water,” Acoust. Phys. 55 (3), pp.383-392 (2009).

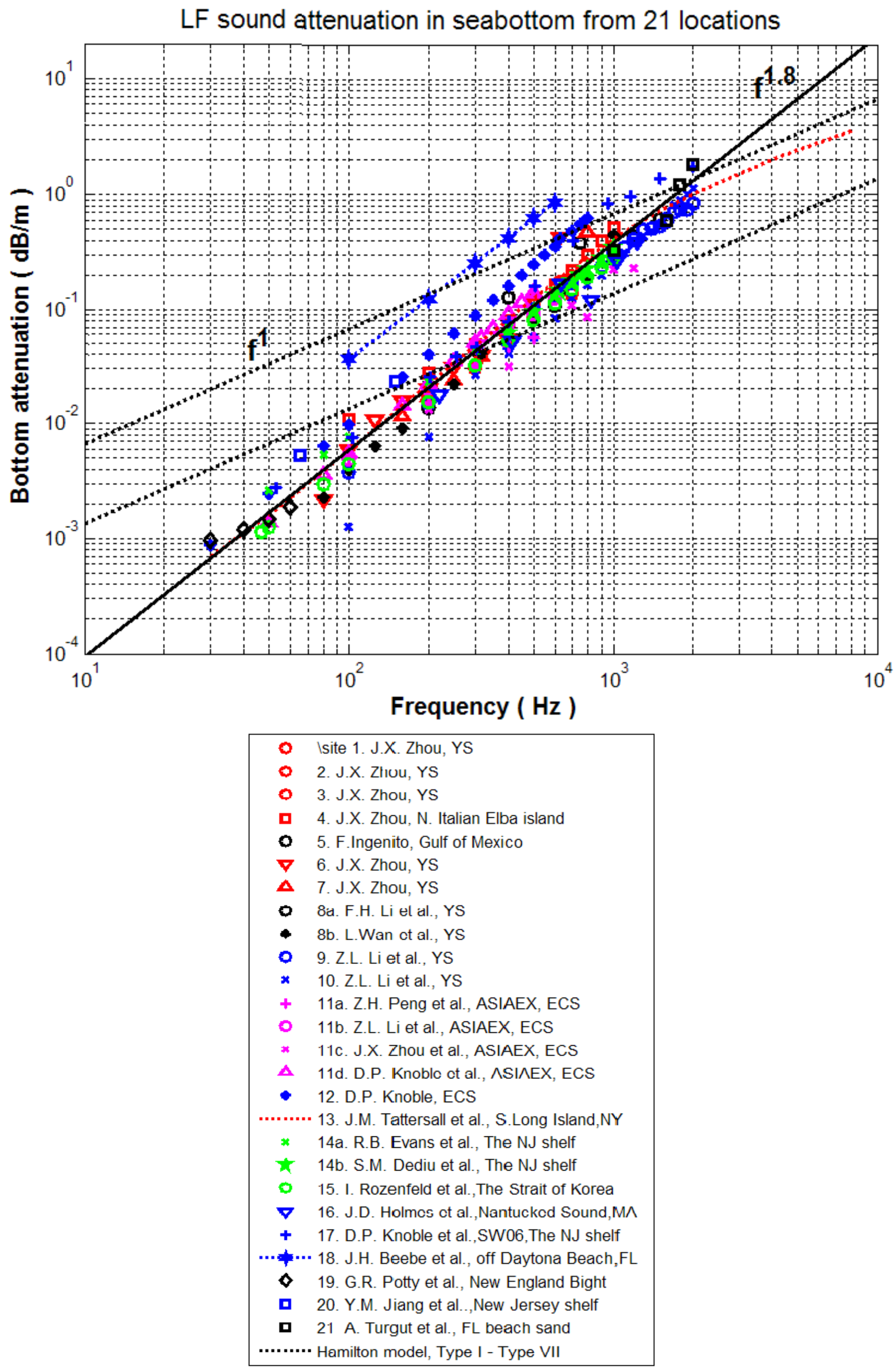

Figure 1. LF bottom sound attenuation from 20 locations in different coastal zone around the world.

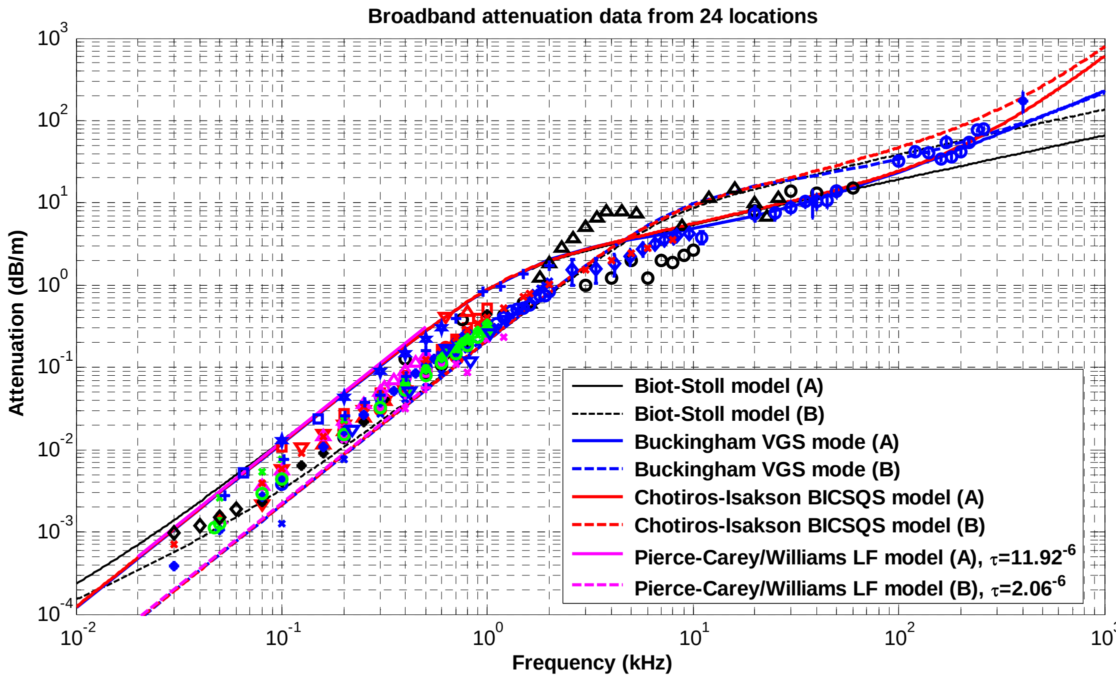

Figure 2. Comparisons of the LF bottom sound attenuation with four geoacoustic models

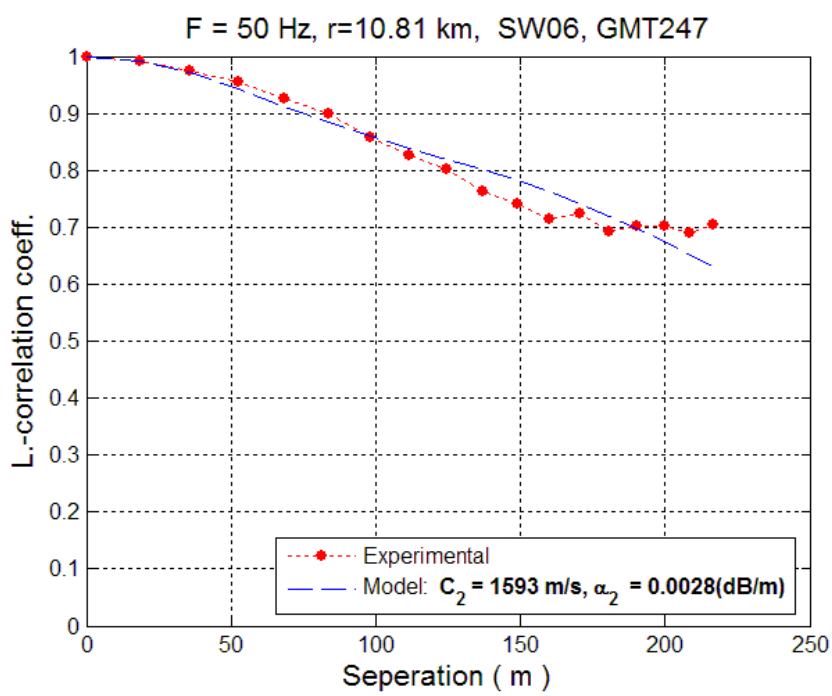

Figure 3. Spatial coherence-based seabed geoacoustic inversion for SW06 site